Marine and Petroleum Geology 39 (2013) 150–163

Contents lists available at SciVerse ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Channel-body basal scours: Observations from 3D seismic and importance for subsurface reservoir connectivity

John W. Snedden*

Institute for Geophysics, The University of Texas at Austin, R2200, 10100 Burnet Rd., JJ Pickle Research Campus, Bldg 196 (ROC), Austin, TX 78758-4445, United States

ARTICLE INFO

Article history:
Received 10 January 2012
Received in revised form
9 August 2012
Accepted 31 August 2012
Available online 13 September 2012

Keywords:
Scour
Connectivity
Channels
Channel-base drapes
Channel-bodies
Bank full
Fluvial
Deep-water
Reservoir

ABSTRACT

Scouring at the base of channel bodies plays a significant role in enhancing connectivity of sandstone reservoirs. Investigation of high-resolution 3D seismic data from a fluvial and deep-water channel system illuminates the location and spacing of channel-body basal scours and possible controls. Scours in both East Breaks upper fan (Quaternary) and Iron River fluvial channel-bodies (Cretaceous) are comparable in scale, with a deviation of up to 10 m scour depth relative to the average channel-body basal depth.

Substrate lithology, as documented by draping well-calibrated seismic response onto 3D channel body basal surfaces, does not appear to be a major influence on scour location or depth. In the datasets examined, channel-body basal scour locations appear to be most influenced by changes in channel orientation, with outer bends being particularly prone to scouring, even in channels that are not highly sinuous.

Scaling relationships between scour spacing and channel width observed in modern fluvial systems are further tested against these high-resolution datasets and published Miocene subsurface deep-water reservoir maps but results are mixed, with a consistent over-prediction of scour spacing. This may reflect difficulties in accurately determining channel bank full width in confined deep-water channel complex systems.

Observations from an ancillary 4D seismic dataset show that over 30% of the identified scour areas exhibit attribute anomalies calibrated with water saturation changes between the baseline and monitor surveys (about 3 years) and thus indicate production-induced fluid movement through these features. This underlines the importance of scours as connection points between fluid compartments and the significance of observations of scour location and spacing made here from high-resolution 3D and ancillary 4D seismic data.

1. Introduction

As large offshore discoveries go through development and established fields progress through their maturity cycle, reservoir connectivity (and its inverse, reservoir compartmentalization) is a growing area of petroleum industry research and operational effort (Jolley et al., 2010). Reservoir connectivity analysis is designed to reveal the internal plumbing of a field or undeveloped hydrocarbon discovery (Vrolijk et al., 2005; Snedden et al., 2007). Reservoir connectivity analysis generally focuses upon two entities: 1) the compartment which contains fluids and has no internal barriers that would allow for more than one fluid (gas, oil, water) contact and; 2) connections between compartments, such as fault juxtaposition windows and channel-body to channel-body contact points (Sweet and Sumpter, 2007; Richards et al., 2010).

Industry experience in global field development and production has demonstrated that one important but poorly understood connection between reservoir compartments is where channel-bodies are in contact (Larue and Hovadik, 2006; Snedden et al., 2007; Funk et al., 2012). This problem extends from non-marine channel systems (de Rooij et al., 2002) to deep marine channel systems (Posamentier and Kolla, 2003; Barton et al., 2010). Connections may occur in both the lateral and vertical sense, but both may impact the vertical movement of fluids during production, depending on the geometry and dip of the reservoirs (Stewart et al., 2008). Early water and gas breakthrough through vertical connections often has a detrimental effect upon ultimate recovery and economics (Fox and Bowman, 2010). Conversely, greater

* Tel.: +1 512 471 0452; fax: +1 512 471 0348.
E-mail address: jsnedden@ig.utexas.edu.

0264-8172/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpetgeo.2012.08.013

connectivity can also improve depletion and enhance recovery (de Rooij et al., 2002).

One approach to connectivity assessment and reservoir simulation is to study and model shales that drape the base or margins of channel-bodies (Stewart et al., 2008; Alpak et al., 2011). Channel-base drapes (CBD's) have been recognized in outcrop analogs and interpreted from logs, cores, and dipmeter or image log data (Barton et al., 2010). However, CBD's generally fall below the resolution of most industry seismic data and thus their 3D distributions are usually unknown (Barton et al., 2010; Sweet et al., 2006).

The 3D continuity of CBD's is clearly linked to depositional processes during channel bypass and filling. One process clearly impacting the 3D continuity of the CBD's and channel-body to channel-body erosional *scouring* (Fig. 1). Scours may be defined as discrete, irregular depressions in channel-body basal surfaces produced by regions of higher turbulence over a relatively long period of time (Salter, 1993). These tend to be smaller scale than the channel-bodies within which these are found and are less continuous than the channel-body basal surface itself, and are found preferentially formed in outer bends, channel confluences, channel mouths and channel constrictions where the thalweg is especially deep (Gibling, 2006; Fig. 1). Scours are observed in modern environments ranging from fluvial to deep-water (Bigelow, 2005; Best and Ashworth, 1997; Wynn et al., 2002; MacDonald et al., 2011).

Scours are particularly important from a reservoir fluid flow perspective as these provide pathways through channel-base drapes and connect stacked channel-bodies. Even with separation

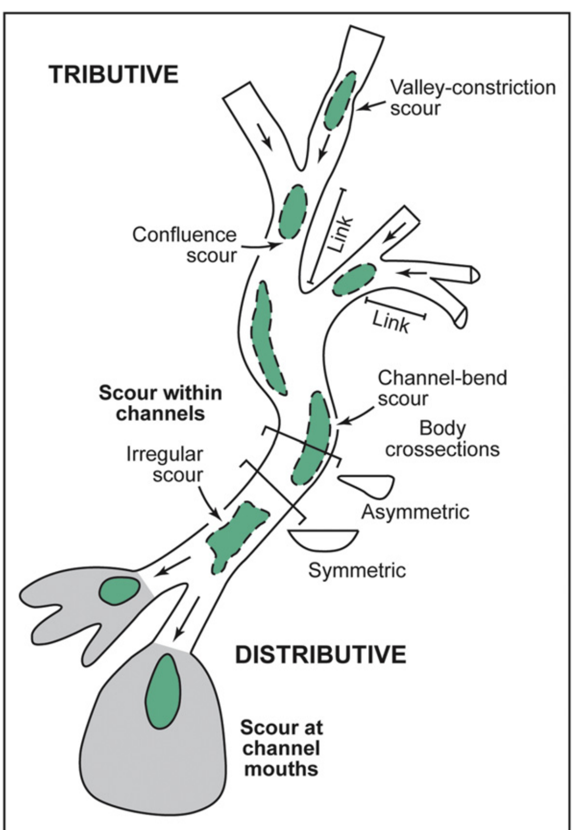

Figure 1. Scour occurrence in natural systems. Modified from Feldman et al. (1995), Plint (2002), and Gibling (2006).

between stacked channel-bodies of as much as 50% of the thalweg depth, as much as 15% of the overlapping channel-body contact area will be scoured (Alexandrowicz and Holbrook, 2008). During deposition, scours may also change the local seafloor morphology and affect the dynamics of the flow, leading to greater channelization elsewhere and enhanced overall connectivity (Eggenhuisen et al., 2011).

While scours are well-documented in modern rivers and near man-made structures, there is a paucity of studies of scours in older natural systems, particularly three-dimensional (3D) descriptions from subsurface realms that may lead to predictive capability. The purpose of this paper is to report observations of scours from two high quality 3D seismic datasets, East Breaks and Iron River. These qualitative investigations are paired with semi-quantitative testing of some empirical relationships derived from modern systems, in order to evaluate the utility of these scaling trends for subsurface reservoir connectivity prediction. Both fluvial and deep-water cases are considered, in order to determine if there are some commonalities in scour location and spacing that are independent of water depth and environment.

2. Definition and occurrence of scours in fluvial and deep-water systems

Scours, as defined here, occur in many natural systems as the process of turbulent erosion is universal (Thompson, 2001). Scours occur both within channel reaches and at channel mouths (Best and Ashworth, 1997; Gibling, 2006; Fig. 1). Scouring is part of the erosional processes often associated with formation of incised river valleys and deep-water canyons.

However, it is important to make a distinction between allocyclic and autocyclic processes that cause erosion in sedimentary systems. Allocyclic controls extend from meter-scale erosion associated with coastal retreat (Swift, 1976) to km-scale unroofing associated with long term tectonics (Flowers et al., 2006). Autocyclic processes like scour also cause erosion of previously deposited sediments and pre-existing stratal successions. However, Salter (1993) made a distinction between extrinsic processes like base level fall that create valley entrenchment and intrinsic processes that produce localized scours in fluvial channels. We employ that same distinction in this paper and focus upon the intrinsic, autocyclic processes that cause channel-base scour and thus create potential vertical pathways for fluid flow in hydrocarbon reservoirs.

Our usage of the terms channel-, -fill, -body, -belt, or valley-fill here follows the definitions of Gibling (2006), Sheets et al. (2007), and Martin et al. (2011). Channels deposit a channel-body, which through aggradation or incision may result in a body that is somewhat thicker or deeper than the original channel itself (Salter, 1993). In some cases, a channel may be filled and abandoned without change in its perimeter (banks and basal surface) and thus is referred to as a channel-fill (Gibling, 2006). Channels may also migrate laterally to form channel belts (Rittenour et al., 2007). Channel fills form multiple channel belts; these are concentrated in major subaerial drainage systems as a valley-fill (Martin et al., 2011). The equivalent of a channel-belt in a deep-water system is generally referred to as a channel complex (Abreu et al., 2003).

2.1. Fluvial settings

Scouring is well known in fluvial settings, as documented in numerous hydrologic, engineering, and morphometric studies (e.g. Balachandar and Kells, 1997; Buhman et al., 2002; Thompson, 2001,